Reverberation Modeling Workshops

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LONG-TERM GOALS

Reverberation modeling is a fundamental tool supporting Navy sonar systems. Because of increased interest in littoral operations, requirements for accurate system performance predictions are placing increasing demands on predictions of reverberation. Requirements for better reverberation modeling are coming from both legacy systems employing new tactics and new distributed autonomous systems needing deployment and control strategies. These demands include better physics and statistical characterizations, required by the need to simulate bistatic and multistatic scenarios in complex (range-dependent) and variable environments using sophisticated wideband signals. Theoretical advances, the availability of high performance computers, and rapidly expanding communication bandwidths have made it technically feasible to implement many of the modeling changes necessary to meet the new requirements. The resulting recent progress in basic and applied research makes this a good time to review current capabilities and propose improvements. These improvements, combined with operational Navy requirements, will help define the way ahead for changes to Navy Standard Models. These models are widely used in applications ranging from training to campaign-level modeling. Currently, there are numerous research models that have had very little in the way of verification and validation – nothing comparable to what has been accomplished by way of benchmarking for forward propagation modeling. Finally, on a related topic, a recent report[1] concerning verification and validation (V&V) of geoacoustic inversion techniques noted the lack of a proven method to generate synthetic reverberation data designed to test these inverse techniques on reverberation data.

The current plan is to hold two workshops – the first in November 2006 and the second late in 2007. The first workshop will concentrate on benchmarking monostatic and bistatic reverberation predictions for littoral environments. The second workshop will expand the focus to include system characteristics (e.g. large bandwidth), higher-order moments, and sources of clutter.

The problems of interest will be restricted to a frequency range < 10 kHz and will concentrate on shallow water environments. The first workshop will concentrate on boundary scattering. Most, if not all, problems will require a narrow-band solution and a broadband solution.

[1] D. King, D. Knobles, J. Perkins, M. Siderius, "Recommendations for the Geoacoustic Inversion Toolkit", NRL Memorandum Report NRL/MR/7140--06-8938 (2006).

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OBJECTIVES

The overarching goals of these workshops are to identify current capabilities and shortfalls and move the state-of-the-art in reverberation modeling forward. The November 2006 Reverberation Modeling Workshop will provide a forum for investigators active in the development of reverberation models to exchange ideas, describe their algorithms, and identify problems or deficiencies. The specific objectives of this workshop will be to:

(a) **Summarize/compare existing models**. This includes inputs, outputs, theoretical basis, assumptions/limitations, and speed. This information will be supplied by participants and compiled by the organizers. Other features of interest, but not easily quantifiable, are flexibility, graphics, physical insights provided, and automation.

(b) **Determine where the cutting edge is in reverb modeling**. In order to define the way forward for future developments one needs two things: An assessment of where we are now, and an assessment of what capabilities are lacking. The workshop will concentrate on the former item, but will also address the latter.

(c) **What is the speed/accuracy of current codes**? This can be viewed as a subset of (b), but is listed separately because it will form a major part of the workshop (see the discussion in the 'Approach' section below).

(d) **Propose an approach to generating synthetic data for use in inverse algorithms**. We expect that, assuming we meet the objectives (a)-(c), this will essentially be a by-product of the workshop.

(e) **Outline future research directions.** This includes 6.1 through 6.4 research and will assist Program Sponsors in prioritizing investments.

APPROACH

(a) Participants will be asked to submit an abstract for a presentation that will detail the essential features of their reverberation model. They will also be asked to submit a paper with a theoretical description of the model, its assumptions, limitations, and performance on the workshop problems (discussed in 3(b)). These papers will follow a common format and form the basis of the deliverable listed in 4(a).

(b) Workshop participants are expected to solve at least one problem from a group of approximately 10 problems. These problems range from monostatic range-independent 2D geometries to bistatic range-dependent 3D geometries. The problems were defined by a Problem Definition Committee consisting of seven reverberation modelers. The committee approved these problems using the criteria that (1) the majority of the reverberation modeling community should be able to solve most of these problems, and (2) the problems should highlight the similarities and differences in the ways the models incorporate the relevant physics. The problems were posted on an ftp web site (ftp://ftp.ccs.nrl.navy.mil/pub/ram/RevModWkshp) on 1 April 2006. Participants were encouraged to begin working these problems and to submit solutions as soon as possible.

This will allow time to correct inadequacies that may be discovered in the problem definitions and allow a participant to submit a new solution if necessary.

These are NOT blind tests, since, generally, a ground truth solution is not available. The organizers will collect the solutions and plot them for comparison purposes. The problems were designed so that the mutual agreement (or non-agreement) of solutions will teach us about the strengths/weaknesses of the various models. [This approach is similar to that taken for the first PE workshop[2] where no ground truth was available. Recent work by Chris Harrison at NURC may provide us with a range of analytical solutions that could be used as rough benchmarks for certain specialized problems.] As noted above, one deliverable for the first workshop will consist of several problems that can serve as benchmark problems for a variety of future efforts in reverberation modeling.

Simply defining these problems was not an easy task. Many models do not have much flexibility in the scattering kernels they employ. This could be a contentious issue. For models that cannot treat the exact scattering problem, we will also provide loss and scattering strength vs. angle and frequency.

The main point that participants should keep in mind is that these problems are to help stimulate and focus the discussions of the workshop, and are not intended as benchmarks. As stated above, we hope that the workshop participants will be able to agree on several problems that can serve as future benchmarks. Time will be allotted for participants to make short presentations on this topic and we hope that the test cases can form the basis for discussion.

(c) Finally, some time will be devoted to defining the objectives for the second workshop.

WORK COMPLETED

A joint memorandum establishing sponsorship of these workshops was signed by the Technical Director, Office of the Oceanographer of the Navy, and the Head of the OBS Department, Office of Naval Research. This memorandum, along with a workshop announcement and call-for-abstracts was distributed by electronic mail to approximately two hundred offices and individuals. Currently we are expecting approximately fifteen models to be represented and roughly forty attendees. The co-chairmen of the workshop are Mr. John Perkins (NRL) and Dr. Eric Thorsos (APL/UW).

The Problem Definition Committee (discussed above) was formed. Dr. Kevin LePage chaired this committee of seven scientists experienced in reverberation modeling. Twenty problems were identified including (1) two- and three-dimensional problems, (2) Lambert's Law problems, (3) problems with both bottom and surface roughness, (4) monostatic and bistatic geometries, and (5) range-independent and range-dependent problems.

The workshop problems (and other relevant information) are available at the anonymous ftp web site listed at the top of this document.

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[2] James A. Davis, DeWayne White, and Raymond C. Cavanagh, "NORDA Parabolic Equation Workshop, 31 March - 3 April 1981," NORDA Technical Note 143 (September 1982).

The workshop site has been reserved. It is the Pickle Research Center in Austin, Texas. Dr. David Knobles (ARL/UT) is serving as the local point-of-contact.

The co-chairmen are currently working with the sponsors to establish the final agenda.

RESULTS

(a) The main deliverable from the first workshop will be a technical report/proceedings detailing the characteristics of each of the participating models and a comparison of the solutions received. A summary of the state-of-the-art and outstanding issues in reverberation modeling will be included.

(b) A key result will be a summary of the approaches taken to represent both the environment and the scattering/loss characteristics for the environment. We intend to begin a process to devise "active community standards" for the scattering environment sufficient to be converted to each model's preferred mode of input.

(c) We anticipate identifying several problems that may serve as future benchmarks. These will be valuable for many efforts including future model developments and geoacoustic inversion.

(d) A recommendation for the objectives and approach for the second workshop will be included.

IMPACT/APPLICATIONS

Please see the discussion under in the **LONG-TERM GOALS** section above.

TRANSITIONS

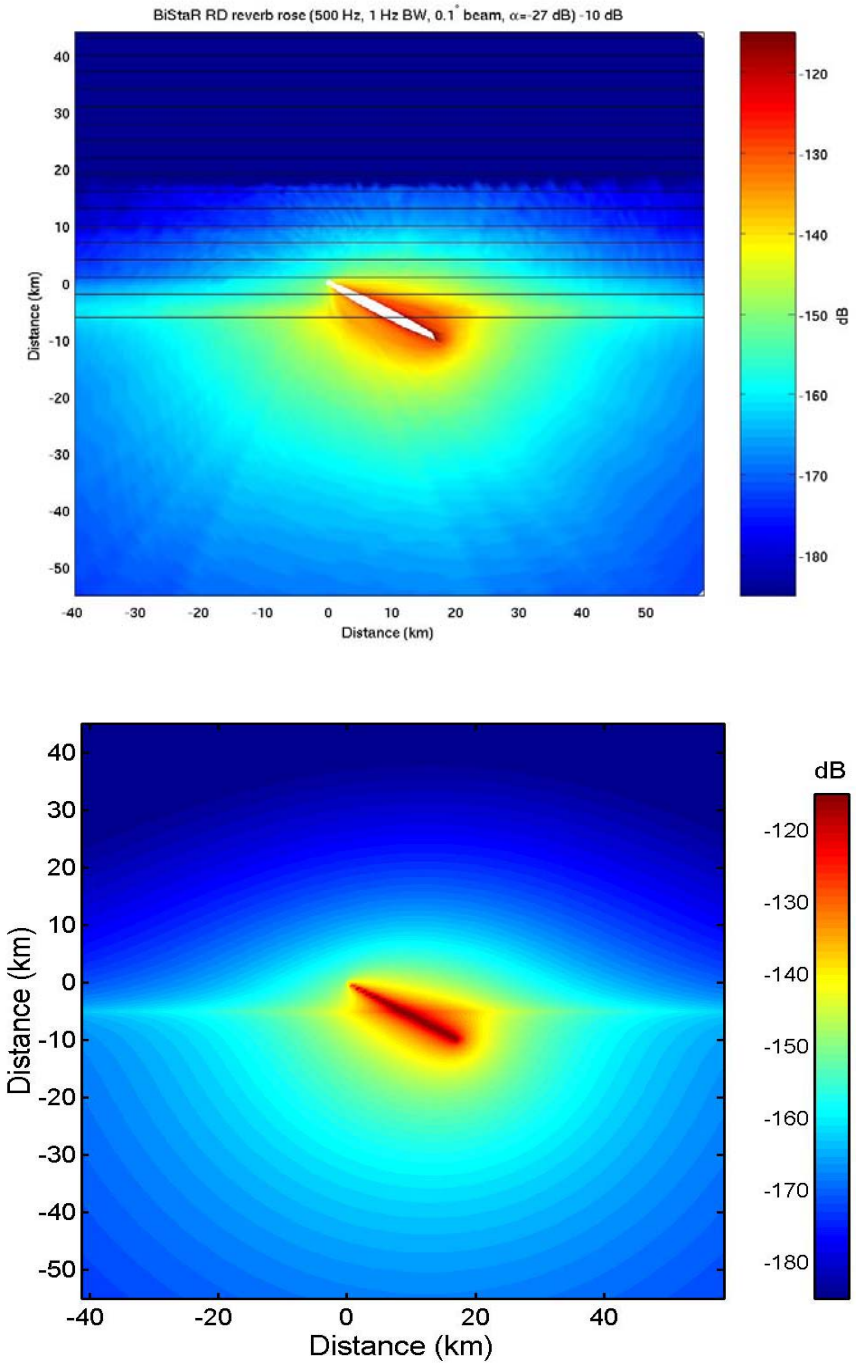
These workshops are being co-sponsored by PEO C4I&Space (PMW-180). Recommendations for new models or modifications to existing models will be made to PMW-180. Also, inverse algorithms that determine geoacoustic parameters from observed reverberation are also potential transitions to PWM-180.

RELATED PROJECTS

There are numerous projects addressing issues in reverberation modeling. This is reflected in the fact that we expect workshop participation from the following research organizations: Applied Research Laboratory, Pennsylvania State University, Applied Research Laboratories, University of Texas, Applied Physics Laboratory, University of Washington, Naval Research Laboratory, Defence Research and Development Canada, NATO Undersea Research Centre, Applied Physics Laboratory, Johns Hopkins University, Northeastern University, Science Applications International Corporation and others.

REFERENCES

D. King, D. Knobles, J. Perkins, M. Siderius, "Recommendations for the Geoacoustic Inversion Toolkit", NRL Memorandum Report NRL/MR/7140--06-8938 (2006).



These plots are the outputs from two bistatic reverberation models. The top result is the output of the BiStaR bistatic reverberation model. The bottom plot is an analytic result of Chris Harrison. The environment is a wedge shoaling towards a 30 m shelf. The source is on the shelf and the receiver is in 80 m of water. An enhancement along the shelf-break (horizontally near the center of the plots) is predicted by both models, and is caused by the minimization of the two-way TL to this region. These results are indicative of the type of inter-model comparisons we seek to compile for a large sample of research and OAML-approved reverberation models.